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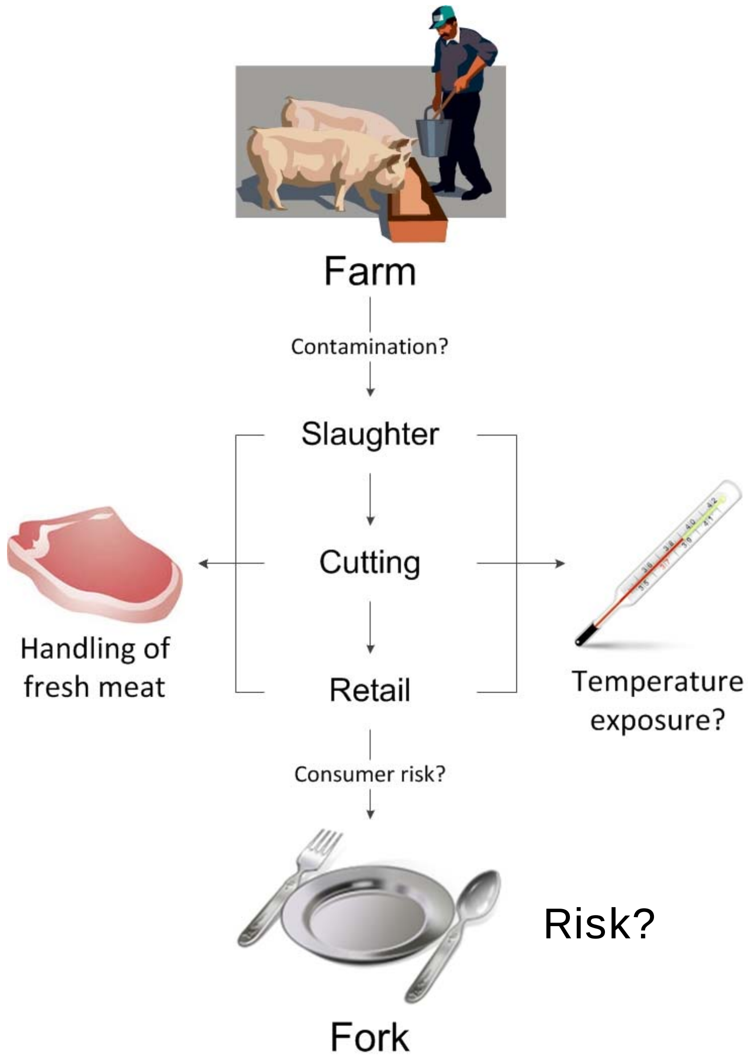
Generic global models for growth prediction of *Salmonella* in ground pork and pork cuts

Tasja Buschhardt, Tina Beck Hansen, Martin Iain Bahl, Donald W. Schaffner, Søren Aabo

DTU Food
National Food Institute

Research background and motivation

- Focus on bacterial populations in meat at slaughter and cutting
- Growth on surfaces
  - Carcasses
  - Meat cuts
- In relation to temperature control
  - Studied acceptable temperatures and temperature-abuse



Predictive models for *Salmonella* growth on pork surfaces?

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ELSEVIER

Effect of natural microbiota on growth of *Salmonella* spp. in fresh pork – A predictive microbiology approach

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- Predictive growth models for *Salmonella* in ground pork and pork cuts
- Two-step regression:
  - Primary: Logistic model with delay
  - Secondary: Square root, RLT, and simple linear N_{max} model
- Interaction models for *Salmonella* and natural microbiota in ground pork

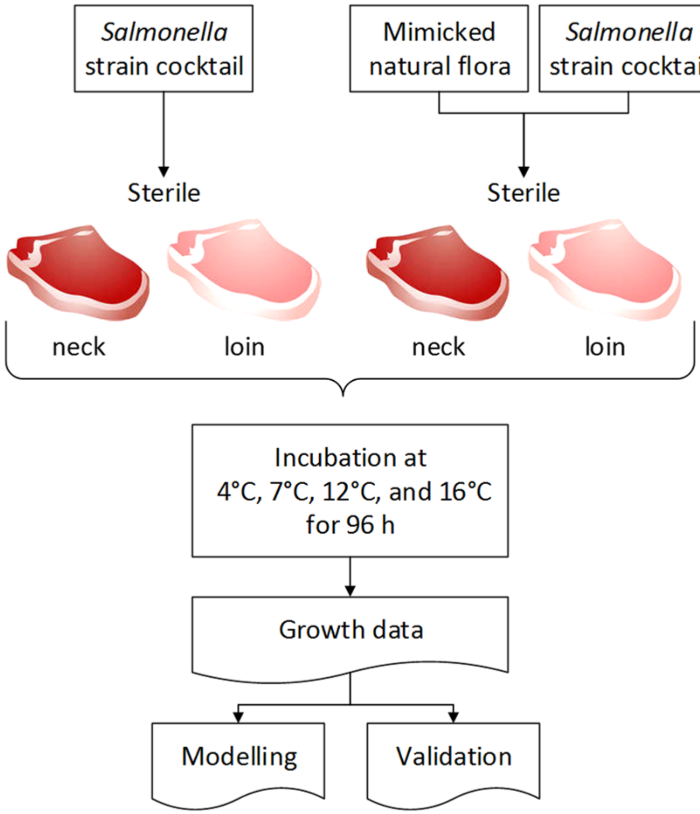
Research questions

- Can the growth model by Møller et al. acceptably simulate growth of *Salmonella* on the surface of sterile pork?
  - If yes :

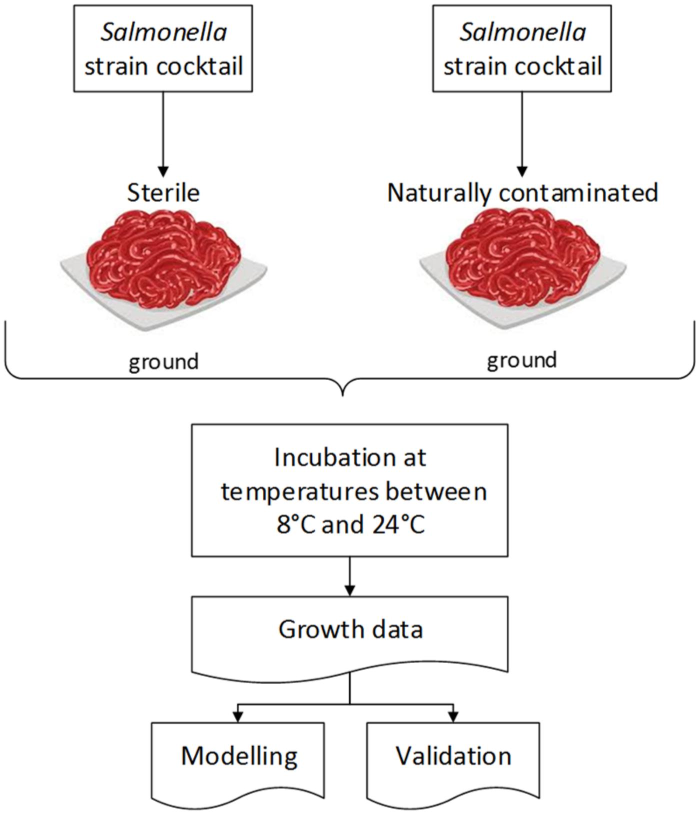
  - If not:
    - Do we need pork product specific growth models?
    - <u>Or</u> can generic growth model be improved?
- Can the interaction model by Møller et al. acceptably simulate growth of *Salmonella* in interaction with the natural microbiota on the surface of pork?

Growth data from challenge tests

From this study



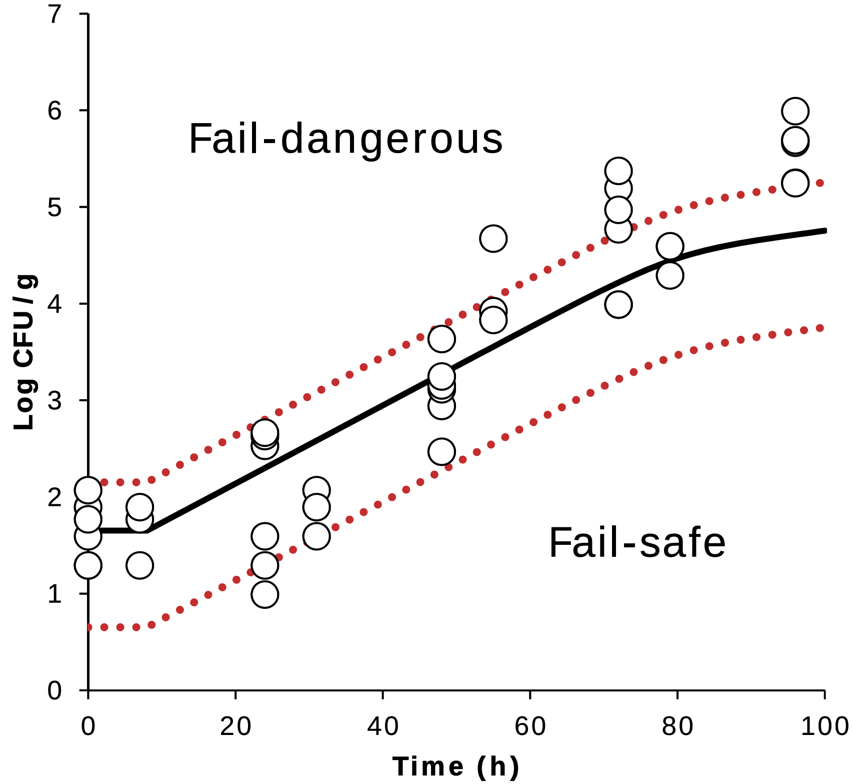
By Møller et al.



Methods for model performance evaluation

Acceptable Simulation Zone (ASZ)

- first introduced by Oscar, 2005
- Compares simulated growth with independent observational data
- Defined as -1 log-units and 0.5 log-units (Oscar, 2011)
- Simulations were considered acceptable when > 70% residuals were within the ASZ



Performance evaluation for Møller et al. *Salmonella* growth models

Salmonella growth model	Pork product	Storage temperature (˚C)	Number of observations included in evaluation	Observations within ASZ (%)	Fail-dangerous (%)	Fail-safe (%)
Møller et al.	neck	12.0	27	89	11	0
		15.0	27	78	15	7
	loin	12.3	15	$\boxed{67}$	7	27
		16.5	15	$\boxed{60}$	3	40

Methods for model improvement

Global regression growth models

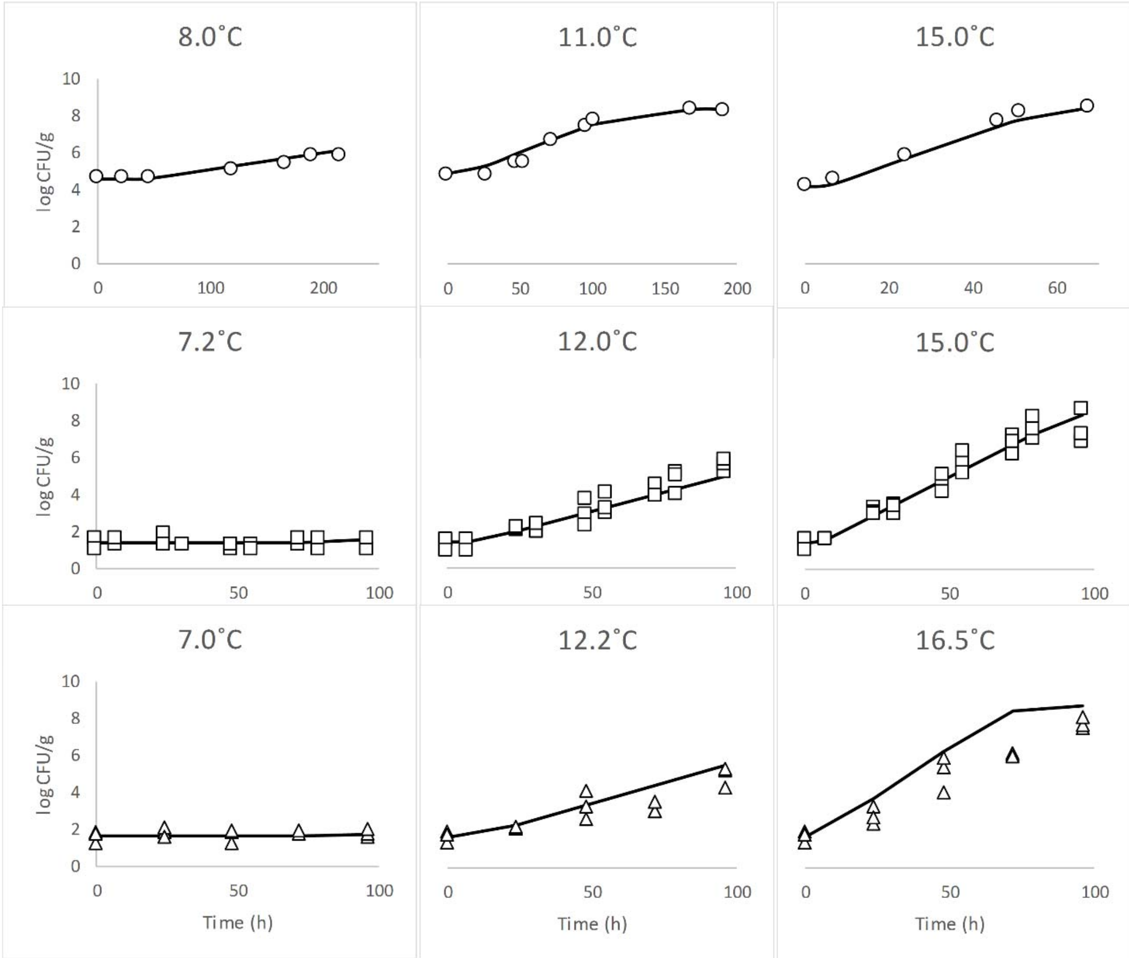
"*a global regression combines the primary and secondary models, giving a direct relationship between experimental factors and microbial counts*" (Martino and Marks, 2007)

$$\mathrm{Log}(N_t) = \mathrm{Log}(N_0) \qquad , t \leq \lambda$$

$$\mathrm{Log}(N_t) = \mathrm{Log}\frac{N_{\max}}{1+\left(\frac{N_{\max}}{N_0}-1\right)\cdot\exp\left(-(b\cdot(T-T_{\min}))^2\cdot\left(t-\left(\frac{\left(k_1\cdot+k_2/T^2\right)\cdot\ \ln(2)}{(b\cdot(T-T_{\min}))^2}\right)\right)\right)}, \quad t>\lambda$$

- Pork product specific models → cross-validation→ generic models

Generic global model- Observed and simulated growth



98% within ASZ
2% fail-dangerous

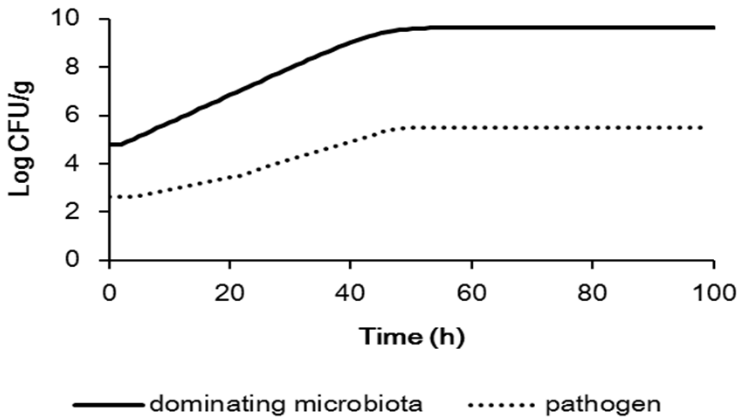
86% within ASZ
11% fail-dangerous

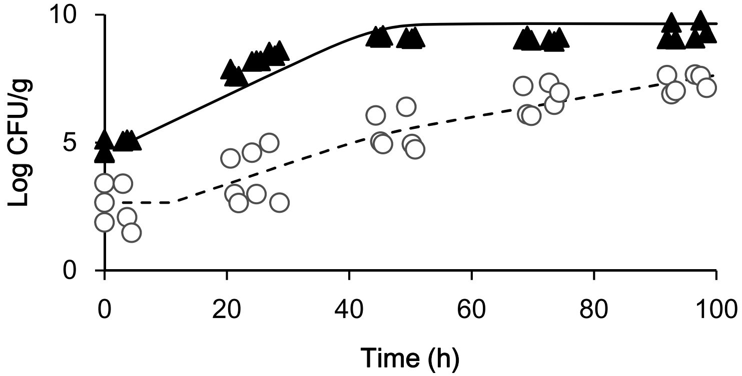
76% within ASZ
22% fail-safe

INTERACTION MODELS

Microbial interaction model by Møller et al.

Jameson effect





Expanded Jameson effect

- Temperature dependent competition factor γ

$$
\begin{cases}
t < t_{\text{lag}-S}, & \dfrac{dS/dt}{S_t} = 0 \\
t \geq t_{\text{lag}-S}, & \dfrac{dS/dt}{S_t} = \mu_{\max}^{S} \times \left(1 - \dfrac{S_t}{S_{\max}}\right) \times \left(1 - \dfrac{\boxed{\gamma \times} \text{NB}_t}{\text{NB}_{\max}}\right) \\
t < t_{\text{lag}-\text{NB}}, & \dfrac{d\text{NB}/dt}{\text{NB}} = 0 \\
t \geq t_{\text{lag}-\text{NB}}, & \dfrac{d\text{NB}/dt}{\text{NB}} = \mu_{\max}^{\text{NB}} \times \left(1 - \dfrac{\text{NB}_t}{\text{NB}_{\max}}\right) \times \left(1 - \dfrac{S_t}{S_{\max}}\right)
\end{cases}
$$

- Effect of temperature on γ was described in polynomial model

$$\text{coefficients of interaction} = a_0 + a_1 \cdot T + a_2 \cdot T^2$$

Performance evaluation of interaction model by Møller et al.

Focus on *Salmonella*

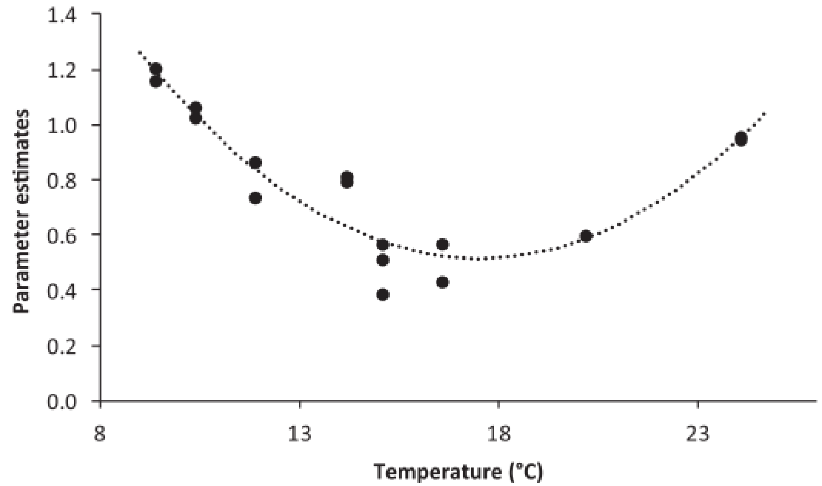
Interaction model	Pork product	Storage temperature (˚C)	Number of observations included in evaluation	Observations within ASZ (%)	Fail-dangerous (%)	Fail-safe (%)
Møller et al.	ground	9.4-15.0	47	**80**	**4**	**16**
	neck	7.2-15	81	**74**	**26**	**0**
	loin	7.2-16	45	**73**	**0**	**27**

?

Methods for model improvement

Global regression- interaction coefficient

coefficients of interaction $= a_0 + a_1 \cdot T + a_2 \cdot T^2$

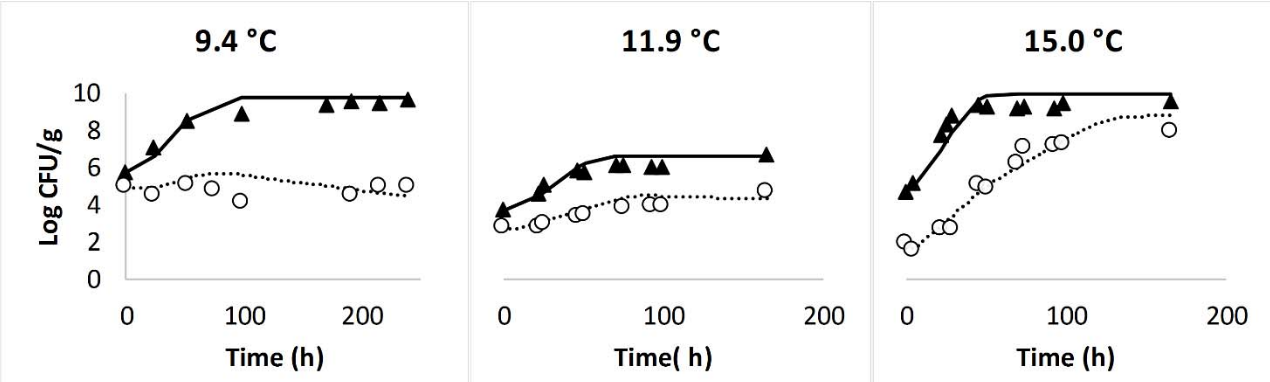


Møller et al., 2013

- To estimated parameter values describing the effect of storage temperatures on γ
- Global fitting of a_0, a_1, and a_2
- Used global generic growth models
- Pork product specific models → cross-validation→ generic models

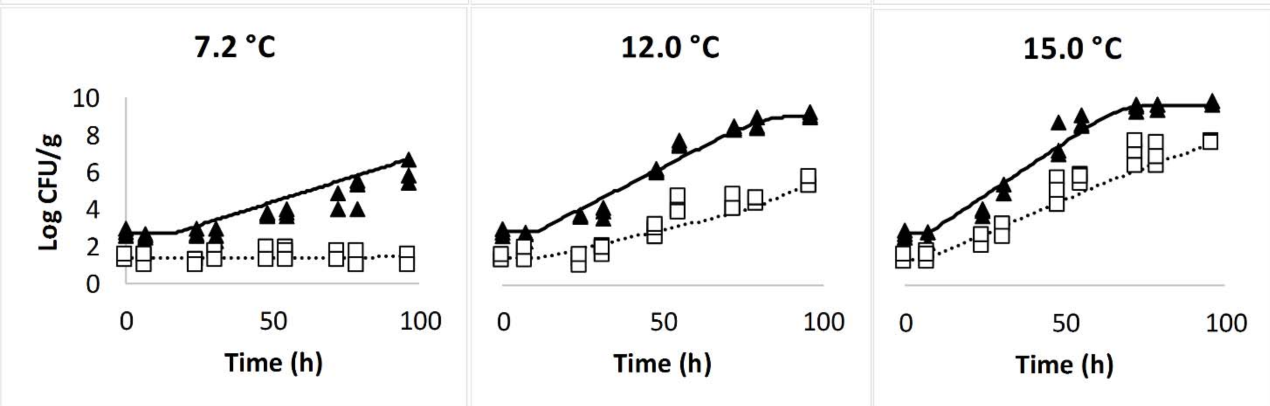
Product specific global interaction models- Observed and simulated growth

ground



85% within ASZ
7% fail-dangerous

neck



83% within ASZ
17% fail-safe

Conclusions

- Growth of *Salmonella* in fresh pork was acceptably simulated by using temperature as the only variable
  - Differences in structure and potential pH differences affected growth but did not hinder the development of a generic growth model

- The growth of *Salmonella* during interaction with the natural microbiota seems to be influenced by pork product structure
  - ASZ principle? Fail-dangerous tendency?
  - Few temperatures & short incubation time → can we “catch” interaction?
  - Variation of natural microbiota should be considered

Thank you for your attention!